Antarctic Polynyas: Ventilation, Bottom Water, and High Productivity for the World's Oceans

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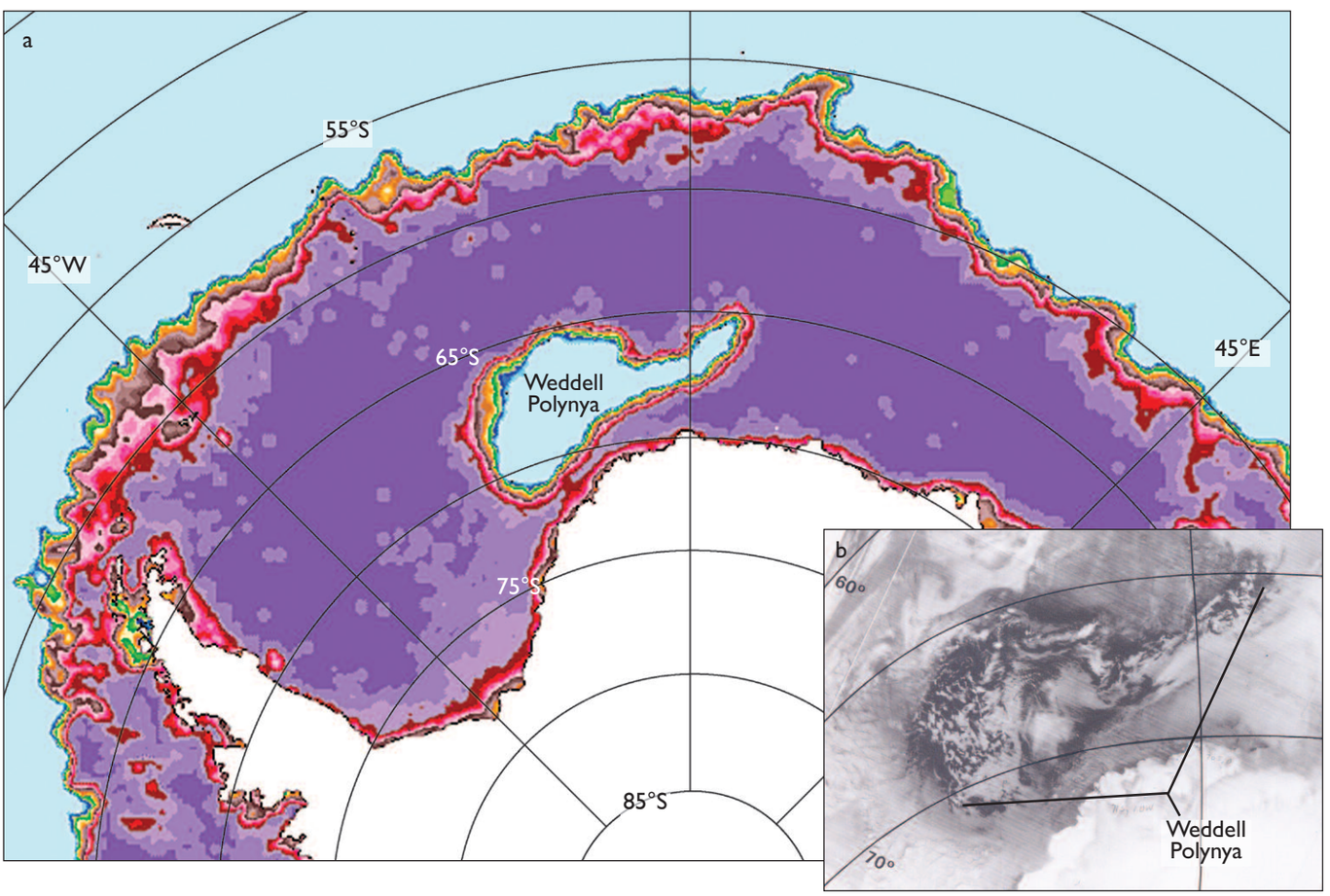
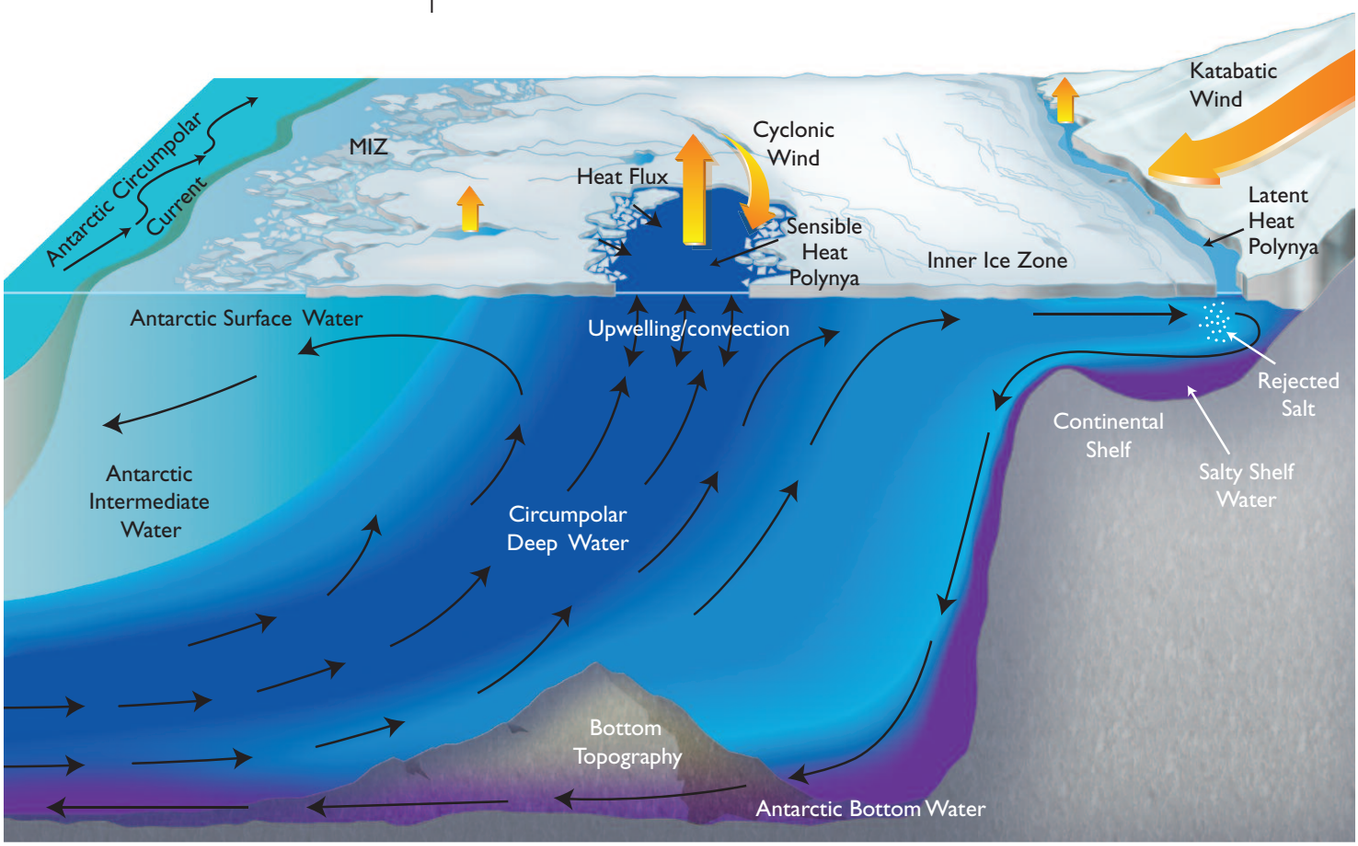


The Weddell Polynya, September 1975. In (a), purple represents highly consolidated ice while light blue represents open water while in (b), black represents open water while white represents ice covered areas or clouds. (Data from the (a) ESMR instrument on the Nimbus-5 satellite and (b) AVHRR instrument on the NOAA-4 satellite.)

The voyages of James Cook and others into the Southern Ocean in the 18th century led to the realization that the Antarctic sea ice cover is very expansive yet changes dramatically, not only with the seasons, but also with winds and currents. Ever since the Belgica was beset in the ice in 1898, many vessels have been forced to "winter over" in the unforgiving ice, including the Magdalena Oldendorff as recently as 2002.

The Antarctic ice pack was generally regarded as a continuous blanket of ice until the advent of images from space in the 1960s, starting with those from TIROS satellites. Early images revealed surprisingly that in addition to innumerable leads (or cracks), there exist large areas of open water within the pack ice, called 'polynyas'. The most spectacular of these polynyas remains the large Weddell Polynya which occurred in three consecutive winters in 1974, 1975, and 1976 and was first observed and monitored continuously by the Electrically Scanning Microwave Radiometer (ESMR) on board the Nimbus-5 satellite.



Schematic diagram illustrating the formation of latent and sensible heat polynyas. (Diagram from Arnold Gordon and Josefino Comiso, modified by Josefino Comiso.)

The passive microwave sensor provided a 24-hour unobscured view of the entire polynya since microwave radiation is insensitive to clouds. This polynya was also observed using the visible channel of the NOAA Advanced Very High Resolution Radiometer (AVHRR) sensor. The Weddell Polynya was unusually large and nearly equivalent to the size of the state of California. In the AVHRR image, the polynya can be seen to be partly covered by clouds which were likely formed due to the unusually high heat and humidity fluxes from the exposed surface of the ocean. Simulation studies using combined sea ice and ocean physical models have indicated the importance of cyclonic winds in at least the initial stages of the formation process for the Weddell Polynya, but wind by itself is not able to explain its sustained duration or reappearance. Oceanographic conditions are therefore believed to play a significant role, through upwelling of warm water over bottom topographic features, like the Maud Rise, maintained in this case by the motion of the Weddell Gyre. As this type of sustained polynya has not reappeared since the 1970s, a debate over the precise formation mechanism continues.

Penguins in front of a polynya. (Photograph courtesy Josefino Comiso.)

The impact on the ocean of such a large polynya event can be dramatic. Hydrographic measurements in 1977 in this region of the waters of the Weddell Sea revealed that the ocean temperature down to 3,000 meters depth had cooled by 0.5°C after the polynya event.